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EFFECTS OF MISALIGNMENT ON MECHANICAL BEHAVIOR

OF METALS IN CREEP

Semi-Annual Status Report

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by

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As mentioned in the previous Semi-Annual Status Report our work is divided into two parts. The first part deals with the derivation of the constitutive creep equation using the endochronic theory of viscoplasticity; the second part deals with the formulation and computational technique of the misalignment problem. The progress of these two efforts during the reporting period is explained separately below:

(A) Derivation of the Constitutive Creep Equation

The endochronic theory of viscoplasticity has been applied to discuss creep, creep recovery, and stress relaxation at the small strain and short time range. We have obtained the following results:

(1) The governing constitutive equations for constant-strain-rate stress-strain behavior, creep, creep recovery, and stress relaxation have been derived by imposing appropriate constraints on the general constitutive equation of the endochronic theory.

(2) A set of material constants has been found which correlate strain-hardening, creep, creep recovery, and stress relaxation.

(3) The theory predicts with reasonable accuracy the creep and creep recovery behaviors at short time.

(4) The initial strain history prior to the creep stage affects the subsequent creep significantly.

(5) A critical stress has been established for creep recovery. The theory predicts that forward creep will occur if the stress at recovery is greater than the critical stress. Otherwise, the normal strain recovery will take place.

To correlate all the above mentioned phenomena, all tests must be conducted for a chosen material using the same heat treatment and

at the same environment. These requirements made it very difficult for us to find useful test data from the literature. The only data that are found useful are those for Aluminum 1100-0 tested at 150°C (300°F). We have compared our theoretical results with these experimental results. The agreement is generally good. These results have been summarized and written as a technical report which is listed at the end of this Status Report and the abstract of the report is also attached. We shall submit this technical report to a journal for publication in the near future.

We would like to add that for the current creep equation, good agreement with experiment has been obtained at the moderate range of creep stress. However, at the higher stress range, good agreement with experiment cannot be found. (We are trying to describe a set of creep curves for various constant stresses using the same set of material constants. If we are allowed to vary the constants, then there is no doubt that we can match the creep curve at high stress level). The future research will aim at the improvement of the creep equation so that good agreement can be obtained at high stress as well.

(B) Formulation and Computational Technique of the Misalignment Problem

We have completed the formulation of the misalignment problem using the creep equation which we have developed. This formulation allows for the small change in stress (increase or decrease) during a creep test.

A computer program has also been written for the misalignment problem. Most importantly, we have been able to get this program running. In this program, we have divided the half length of the specimen into five sections. In addition, we have divided each cross

sectional area into four regions. Since the creep rate in each region of a cross section is different from any other region of the same cross section at all time, and the same problem holds true for stress as well, to discretize the continously varying creep rates and stresses and still be consistent with the set of equations constituted a major challenge regarding to formulation and programing of the misalignment problem. The equations involved are highly nonlinear and we need to solve a set of 52 equations. The NON-LIN package from NASA is quite helpful in providing a more stable program and less sensitive to the initial input.

This computer program is costly in terms of computer time. This is due to the fact that creep is a strain-rate as well as strain-rate history dependent phenomenon. To compute the creep strain for a time step, we need to integrate from the beginning of the creep test for each time. Thus, the longer time we desire to compute for the creep phenomenon the more integration we need to perform and the more computer time needs to be consumed.

Our future work will concern with the finalization of the formulation and the computer programing of the misalignment problem. We hope to generalize the program so that we can perform more refined calculations. Also, we will be working with the more practical side of the misalignment problem, which includes the estimation of misalignment errors for various specimen dimensions.

The following publications are related to this project:

(1) Wu, H.C. and Rummler, D.R., "Analysis of Misalignment in the Tensile Test", Eighth U.S. National Congress of Applied Mechanics, Abstracts, p. 48, University of California, Los Angeles, June 26-30, 1978.

(2) Wu, H.C. and Rummler, D.R., "Analysis of Misalignment in the Tension Test", The ASME Journal of Engineering Materials and Technology, Vol. 101, pp. 68-74, January 1979.

(3) Wu, H.C. and Chen, L., "Endochronic Theory of Transient Creep and Creep Recovery", Report G302-79-001, Division of Materials Engineering, The University of Iowa, April 1979.

ABSTRACT

Short time creep and creep recovery have been investigated by means of the endochronic theory of viscoplasticity. It has been shown that the constitutive equations for constant-strain-rate stress-strain behavior, creep, creep recovery, and stress relaxation can all be derived from the general constitutive equation by imposing appropriate constraints. In this unified approach, the effect of strain-hardening is naturally accounted for when describing creep and creep recovery.

The theory predicts with reasonable accuracy the creep and creep recovery behaviors for Aluminum 1100-0 at 150°C. In particular, it has been found that the strain-rate history at prestraining stage affects the subsequent creep. A critical stress has also been established for creep recovery. The theory predicts a forward creep for creep recovery stress greater than the critical stress. For creep recovery stress less than the critical stress, the theory then predicts a normal strain recovery. The above prediction agrees with the experimental observation reported in the literature.